Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/213
UNITED STATES
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

HIGH-TEMPERATURE GAS-COOLED REACTORS

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The first HTGR 40-MW(e) power plant in the U. S. is nearing completion at Peach Bottom, Pennsylvania. Design and experimental work on full-scale HTGR plants ranging from 200 MW(e) to 1000 MW(e) have been carried out since 1960. Research and development for Peach Bottom have been intensively conducted for the past 5 years under a joint program between the U. S. Atomic Energy Commission and General Atomic. The Peach Bottom 115-MW(th) reactor employs all-graphite, vented fuel elements with coated U/Th carbide particles and with surface temperature up to 1100C. Helium from the reactor at 750C generates superheated steam at 538C by means of a new design of nuclear steam generator.

Other new features in the construction of Peach Bottom include (a) appropriate helium-coolant circulation equipment; (b) fission-product trapping and helium-purification system; (c) new type of refueling equipment; and (d) control rods of B_4C dispersed in graphite for high-temperature operation with hydraulic motor drives.

Research and development for the HTGR have involved all phases of reactor physics, materials development and component design and testing. Results of work in the areas of neutron thermalization in crystalline moderators and in resonance capture theory have been incorporated in an extensive library of reactor-core computer codes. Critical-facility experiments were conducted and checked closely with calculation. These were used to obtain design data for the new semi-homogeneous, graphite core design and for verifying temperature coefficients and control rod worth. Materials development work has included extensive testing, both in-pile and out-of-pile, of low permeability graphites, graphite matrix fuels, and pyrolytic-carbon-coated fuel particles of (U,Th) dicarbide. Results on more than 40 fuel compacts and several hundred samples

of graphite irradiated in capsules under different conditions of exposure and temperature have been obtained.

Proof testing of full-diameter graphite, vented fuel, as well as the associated fission-product-trapping and helium-purification principles, has been carried out for 35 months in the GAIL loop. As of January 1964, fuel elements have reached 37 500 MWd/ton average and 50 000 MWd/ton peak burn-up.

Prototype fuel production experience on a pilot line has included fabrication of almost 2000 kg of coated fuel particles during the latter half of 1963 for the first Peach Bottom core. Good results were obtained in meeting specifications for particle structure, composition and integrity.

The Peach Bottom plant is being built for Philadelphia Electric Company and 52 utilities of the High Temperature Reactor Development Associates group. The entire nuclear steam supply including the reactor and fuel elements are being furnished by General Atomic. Bechtel has engineered the power plant and is constructing it.

General Atomic design and development for larger HTGR plants have included work on 1) a 500-MW(e) plant scaled up from the prototype plant employing a six-steam-generator-loop system and new compact arrangements in the reactor core/vessel and in the over-all plant layout; 2)work on a 250-MW(e) plant of more advanced design employing a concrete pressure vessel enclosing the entire primary circuits; and 3) work on a 1000-MW(e) reactor with concrete pressure vessel with special attention to the possibility of thermal breeding in the U-233/thorium cycle. These programs are being undertaken respectively with the ESADA group of utilities, the ARDA group of utilities, and the USAEC.

There has been extensive development and testing of the graphite fuel to the equivalent of six-year in-core life and fabrication and testing of control drives and fuel-handling equipment for the large plants. Detailed large HTGR designs have efficiencies of 40 to 45 percent using conventional plant steam cycles with reheat. Larger size also improves neutron economy and, with improvements in fuel cycles, results in conversion ratios in the 0.8 to 1.05 range. Projected fuel-cycle costs for 500 MW(e) plants are in the range of 1 to 1.5 mills per kilowatt hour.